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A STUDY OF BACK-LIFT STRENGTH WITH
ELECTROGONIOMETRIC ANALYSIS OF HIP ANGLE

by



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A THESIS

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THE UNIVERSITY OF ALBERTA
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Study of Back-Lift Strength with Electrogoniometric Analysis of Hip Angle," submitted by Thomas Edwin James Ashton in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this study was to investigate differences in effective back-lift strength scores when the hands were allowed to grasp the bar and when a new shoulder harness with self-contained bar was used, which eliminated the use of hands. A sub-problem was to measure the changes in hip angle and the angle at which the maximum back-lift occurred.

Four methods of measuring back-lift strength were administered to twenty-four male student volunteers in attendance at The University of Alberta. Each subject participated in the four tests after having been randomly assigned to one of twenty-four possible testing orders. Test A involved the use of the traditional bar and experimental back-lift dynamometer with no restriction of backward lunging. Test B was the same as Test A except a vertical board connected to the back-lift dynamometer was used to prevent backward lunging. Test C involved the use of an experimental shoulder harness and bar, and the experimental back-lift dynamometer with no restriction of backward lunging. The subjects were not allowed to use their arms and hands in any way on Test C, but were instructed to let them hang at their sides. Test D was identical to Test C with the exception of the vertical board to prevent backward lunging.

Along with the above testing procedures an electrogoniometer was attached to the left hip of each subject for each test to measure changes in hip angle and the angle at which maximum lift occurred.

Analyses of variance did not show significant differences among the means of the maximum scores or among the means of the mean scores of trials two and three for the different tests.

A significant relationship was found to exist between back-lift score and the corresponding angle of the hip for Test B, Test C, and Test D. With this fact taken into consideration, analyses of variance did not show significant differences among the means of the maximum scores or among the means of the mean scores of trials two and three for the different tests.

Using the maximum scores and the means of trials two and three, a definite pattern in the descending order of means was noted. These means for tests always descended from high to low in the order of Test C, Test A, Test B, Test D.

Test Method B was found to have the least standard error of measurement.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Strength tests, even though they do not measure all aspects of fitness as the physical educator views the problem, do deal with a basic element of the individual's general physical status. They have been used successfully in practical field situations, both as a means of selecting students for remedial and developmental classes and for general classification in physical activities (2).

The idea of using strength tests as a measure of physical condition is not new. Nor is the idea of combining them into a formal battery for the purpose of measuring athletic ability a new one, for Dudley A. Sargent, M.D., in 1880, proposed such a battery in which the individual elements were measured by calibrated mechanical instruments. It was not until 1925, however, when Dr. Frederick Rand Rogers standardized testing procedures and developed norm tables for their interpretation, that the relationship between physical condition, athletic performance and muscular strength was demonstrated (8).

In constructing his Physical Fitness Index (P.F.I.) battery, Rogers tried to include only tests that would measure most of the large muscles of the body. As a result, he came up with a composite test of seven elements: pull-ups, push-ups, leg lift, back lift, right-grip strength, left-grip strength, and lung capacity using a wet spirometer. The P.F.I. is determined by comparing the Strength Index (S.I.), a gross score obtained from the strength and lung capacity tests, with norm tables for age, sex, height, and weight (10). An individual's S.I. score is divided by a norm score and the quotient is multiplied by one hundred thereby determining the P.F.I.

Rogers' work was followed by studies dealing with strength as a measure of health and physical fitness. The evidence presented did not substantiate strength tests as valid measures of physical fitness. Other studies supported Rogers' original conclusion of the significant relationship of strength to general athletic ability (5).

Some revisions have been made in the original Rogers' P.F.I., although the test items remain the same. One essential test in both the Sargent and Rogers' batteries is the back lift performed with a dynamometer (4).

The back lift is a test of the strength of the back extensors as registered on a dynamometer during the performance of a vertical lifting movement. The back dynamometer used in the administration of the back-lift test is usually mounted on a small platform. A steel bar about twenty to twenty-two inches long and one inch in diameter, with a strong hook at its midpoint, is connected by means of a steel chain at least twenty-four inches long to the dynamometer base. The subject stands on the dynamometer base, with feet parallel and about six inches apart. The malleoli of the ankle joint should be opposite the attachment of the dynamometer to its base. With the subject's head erect, back straight, and fingers extending down the thighs, the examiner holds the bar at the tips of the subject's fingers to obtain proper adjustment. The bar is then connected to the chain. The subject bends slightly forward, with knees straight, and grasps the bar near both ends. The grip is mixed, one hand forward and one backward. The subject is asked to lift straight up while the examiner spots by placing his hands over the subject's hands to prevent the latter's hands from slipping. The maximum strength score of at least two trials is read from the dynamometer to the nearest

five pounds and is recorded (2), (5), (6), (9).

The above procedures have undergone some change from Rogers' original recommendation for use with the P.F.I. Some of these changes will be discussed in Chapter II.

The Problem

Research in general dealing with the back-lift strength test subsequent to Rogers' study is definitely lacking. The method of testing effective back strength, as prescribed by Rogers, has been accepted without much argument to the present day. Most studies have taken this method for granted as testing effective back strength. However, there are factors involved with the test that raise doubts as to its validity and reliability.

What about the effect of the use of arms and hands? It is observed that the hands usually slip somewhat from the bar, perhaps "giving out" before the back does. Taping the bar helps somewhat, and strapping the subject's hands to the bar results in an even higher effective strength index (3).

In addition, if the subject stands too far forward, he tips backwards; if he stands too far backward, he can increase his leverage by swaying backwards and hence "make" a spuriously large lift (7). Within these two extremes are varying degrees of tipping backwards and swaying backwards (lunging) to achieve a spuriously large lift.

As a result, there seems a need for a more standardized testing procedure. This need is emphasized in an observation of posture and lumbar pull (1). In administering the test, it is important that the knees be kept extended and the handle of the dynamometer be adjusted to the height of the subject's middle finger tip.

This study will be concerned with determining whether or not there

is a significant difference between effective back-lift strength scores when the hands are allowed to grasp the bar and when a new shoulder harness and self-contained bar that connects directly to the experimental back-lift dynamometer is used without hands and arms. In this light, the study will be attempting to analyse back-lift strength with a view to establishing a means of more accurately assessing effective back-lift strength. A sub-problem will be to measure continually the subject's hip angle by means of an electrogoniometer to determine changes in angle at the hip and the angle at which the back-lift score (maximum lift) occurred. Four different methods of administering the back-lift test will be compared.

The null hypotheses for the problem are:

1. That the means of the four test groups shall be equal.

$$H_0: U_A = U_B = U_C = U_D$$

2. That the means of the three trials shall be equal.

$$H_0: U_1 = U_2 = U_3$$

3. That back-lift scores are independent of the hip angle at which they occurred.

$$H_0: \text{No interaction between score and corresponding angle.}$$

Limitations of the Study

1. Errors in calibration and testing precision.
2. The "shout method" will be used for motivation.
3. Degree of perfection of experimental shoulder harness.
4. Number of trials used.

Delimitations of the Study

The study will be delimited to a sample of twenty-four male student



volunteers at The University of Alberta.

Definition of Terms

Muscular Strength. The ability of an individual to exert maximum strength in a single muscular contraction.

Static Strength. The ability of an individual to squeeze, push, or pull an instrument, or to hold the body in one position over an extended period.

Dynamic Strength. The ability of an individual to lift the body weight or propel it in any direction.

Back Lift. A test of the back-lift strength of the extensor muscles of the back by having the subject, with legs straight, lift vertically and maximally with his back and recording the lift score on a back dynamometer.

Backward Lunge. A quick, forceful backward impulse at the hips while the legs are straight, causing a resultant force to be measured on the dynamometer that is not primarily a lifting force.

Traditional Back-Lift Method. The back-lift test using a steel bar about twenty inches long and one inch in diameter with a steel hook attached at the midpoint on the bar, a length of cable, and the experimental back-lift dynamometer.

Experimental Back-Lift Method. The back-lift test using an experimental shoulder harness and self-contained bar and the experimental back-lift dynamometer.



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CHAPTER II

REVIEW OF THE LITERATURE

The back-lift test, as it is used nowadays, came into being in the Rogers' Test Battery in 1925. In 1927, the indices (P.F.I. and S.I.) were first used as administrative measures to classify pupils and equalize athletic abilities of opposing teams (26). Since that time the battery has been used by schools, Y.M.C.A.'s, colleges, and universities.

Rogers believes that the tendency in some quarters to omit the back-lift test as either insignificant or costly is seriously to be criticized, especially if test batteries are used to measure physical fitness. Rogers (26) urges that,

Physical educators who wish to measure physical fitness, gross physical powers, or general motor ability - the qualities of character most affected by large muscle activity - should cleave as closely to strength tests and techniques as possible, spending their resources in researches which use them, rather than seeking ad infinitum for alternative tools of measurement.

As a result of this tendency, very few studies dealing specifically with back-lift technique have been done in the past thirty-five years. Attempts have been made to approach the problem from different angles, rather than make the original model more efficient. These and various other associated studies are discussed below and are arranged according to the subject with which they were concerned.

Factors Involved in the Back Lift

The back lift, because of the complexity of its execution, is affected by more variables than the other test items in the P.F.I.

Body Position and Angle of Pull. If the subject stands too far forward, he tips backwards, and if he stands too far backward, he can increase

his leverage by swaying backwards and hence "make" a spuriously large lift (25).

There has been a number of studies conducted to determine the amount of strength which can be applied by the same muscles when body parts are in different positions. In a study on the effect of limb position on the ability to utilize maximal contractile force of limb muscles, Hugh-Jones (18) found that push and pull amounts increase with extension of the acting joint until the maximum is reached just before the joint becomes straight. This factor has long been recognized by physical educators in back-lift testing with conventional spring-type dynamometers (6).

If the basis for human strength were purely mechanical, the angle of pull would dictate the relative magnitude of the torque being interpreted as the strength value. Therefore, if physiological mechanisms were discounted, one should be able to predict the relative strength values from angles of pull. For example, an angle of pull of ninety degrees in elbow flexion should lead to the maximum strength score for every individual tested in that attitude (3). Even though this prediction value of the angle of pull is questionable, investigators have observed that strength values do tend to vary with changes in the angle of pull. However, there is a lack of experimental evidence relative to the significance of these strength differences (3).

Studies have been done on angles in relation to leg strength with a back and leg dynamometer (4). However, there appears to be a lack of research with regard to the back lift in this same vein.

Age. In a study done by Clarke and Wickens (11) on forty boys, at each age from nine to fifteen, from Caucasian public schools in Medford,

Oregon, the back-lift mean growth curve was derived. The curve had a relatively slight increase during ages nine to ten, a deceleration at eleven years, a pronounced and nearly straight line rise from ages eleven to fourteen, and some deceleration at the age of fifteen years. The mean back lift of the fifteen year olds was more than twice as large as the nine year olds, since means of 148 and sixty-nine kilograms represent an increase of 115 per cent. The standard deviations increased with age. For back lift, increases in standard deviations between fourteen and fifteen years of age were slight, i.e., 16.22 and 24.72 kilograms.

In a similar study on 125 native Indian boys in the Province of Alberta, Singh, Howell, and Macnab (29) found the back-lift mean growth curve to have a relatively slight increase during ages nine to eleven, a slightly greater increase from eleven to thirteen years, and an even more pronounced rise from ages thirteen to fifteen. The standard deviations also increased with age except at eleven years.

In a dynamometer strength study of males thirty to seventy-nine, Donnelly (12) concluded that adults participating in recreational sports programs were stronger than non-participants, but the differences were not statistically significant. Among those participating in recreational sports, the ones who were athletes in high school or college were stronger in back and total strength than non-athletes. Weaker individuals lost a greater proportion of their strength than stronger individuals.

Somatotype and Anthropometry. Willgoose (32) found significant relationships between body types and performance on the P.F.I. The highest mean score was obtained by the mesomorph-ectomorph group and the next highest by the extreme mesomorphs. He concluded that endomorphy is a limiting factor in physical fitness and that mesomorphy is associated

with physical fitness as measured by the P.F.I.

On the back-lift item, means of 381.20 pounds for ectomorphs, 406.90 pounds for endomorphs, and 475.30 pounds for mesomorphs were attained by Sills and Everett (28) in their study on forty-three University of Iowa students. The difference between mesomorphs and endomorphs was significant at the ten per cent level; the difference between mesomorphs and ectomorphs at the one per cent level; and the difference between ectomorphs and endomorphs at the thirty per cent level. They concluded that the mesomorphs were stronger than the endomorphs and ectomorphs; that the endomorphs were stronger than the ectomorphs although statistically significant differences were not obtained; and that excess weight is a handicap to the endomorphs and insufficient strength is a handicap to the ectomorphs in performing physical tests. They also concluded that consideration should be given to body type in formulating standards for achievement on strength tests.

Clarke (9) correlated back-lift strength with various anthropometric measures. In his study on fifty-three unselected, nondisabled male students at the University of Oregon, a number of relatively high correlations were obtained with back-lift strength. The correlations were as follows: 0.61 with hip width and knee extension strength, 0.58 with body weight, 0.51 with trunk-flexion strength, and 0.50 with trunk lateral-flexion strength. These results were all significant beyond the 0.01 level. A multiple correlation of 0.71 was obtained between back-lift strength and knee-extension strength, hip width, trunk-flexion strength, and knee-flexion strength.

Posture. Flint and Diehl (14) in testing 210 school girls from three Santa Barbara City elementary schools found a relationship between the strength of the back-extensor muscles and antero-posterior alignment of the trunk to be significant at the 0.05 level. However, Flint (13)

found no significant relationship between the position of the gravity line and back-muscle strength when testing 117 elementary-school girls (six to twelve years old) from three Santa Barbara City elementary schools.

Training. Clarke (5) analysed the P.F.I. test scores achieved by 914 air-crew students at the close of a three to five month physical training program at Syracuse University. The median score for the back lift was 520 pounds; the range was from 330 pounds to 800 pounds; the interquartile range was 120 pounds; the standard deviation was eighty-six pounds; and the twenty-fifth and seventy-fifth percentiles were 465 and 585 pounds respectively. The above gives some idea as to the scores that may be achieved on the back-lift strength item.

In a study done by Baley (1) on 104 students enrolled in four low-fitness, one middle-fitness, and one high-fitness class in the basic physical education classes at the University of Connecticut who participated in a four-week program of isometric exercises done with an adjustable nylon belt, varying gains in back-lift strength were recorded. When all groups were treated together, a mean gain of fifty-seven pounds was made in the back-lift. This was significant at the 0.0005 level. The high-fitness class made a greater improvement in the back-lift. Classes which did only isometric exercises for half an hour three times per week for four and one-half weeks made greater mean gains in back lift than did classes which met for sixty minutes twice a week for four and one-half weeks and did stretching exercises and running in addition to the isometric exercises. It should be noted that in both the initial and final mean scores in the back lift, the low-fitness classes had the lowest scores and the highest fitness classes had the highest scores. This is another indication of the importance of strength in total fitness.

Back Strength Endurance. Tuttle, Janney, and Salzano (30) were responsible for the construction of a back and leg dynamometer based on the strain-guage technique, designed for measuring and recording both maximum strength and strength endurance. From their test of twenty-three men between twenty-four and forty-six years of age, approximately one-half of the subjects were able to exert measurable back-strength force for only a little longer than thirty seconds. The data showed that the correlation of maximum strength and strength endurance based on a thirty-second effort was 0.97. On a sixty-second effort, the correlation was 0.90. This means that an individual with greater maximum back strength can maintain a higher level of back strength for the periods of effort investigated, namely, thirty or sixty seconds. When the strength endurance is divided by the maximum strength to express the former as a percentage of the latter, and these percentages are correlated with maximum strength, it is seen that the correlations are negative. For the thirty second effort, $r = -0.81$. For the sixty-second effort, $r = -0.48$. This means that an individual with greater back strength cannot maintain as large a percentage of it as an individual with less maximum back strength, even though the former's absolute strength endurance is larger than the latter's. This implies that strength endurance does not develop in direct proportion to maximum strength.

Administration and Standardization

As was mentioned in Chapter I, the back lift should be performed with the knees kept straight and the back bent slightly (6). The subject stands at attention with the malleoli of the ankle joint opposite the chain and with the hands on the front of the thighs. The tester hooks the handle into the chain so that the top of the bar is just below the tips of the subject's fingers. The subject is instructed to bend forward



at the hips with one palm facing forward and one backward, and grasp the bar at the ends. He must then wrap his hands partially around the bar in order to gain as much aid from the friction of the skin of the hands as possible. He is then to lift steadily but as vigorously as possible, and after a maximum lift, release his pull rather slowly (25).

However, if the friction between the hands and the bar is not sufficient to hold the hands securely to the bar when taking the test, the maximum back strength cannot be determined (17). Directions for the test administration just say to grasp the handle with one palm forward and one backward. Sometimes the handle is taped; sometimes the subject's hands are grasped by the tester. These procedures are to increase friction between the hands and the bar and reduce slippage. Hinojosa and Berger (17) did a study on fifteen male college students to determine what techniques of grasping the handle-bar would result in the highest back-strength score. Five different testing techniques were administered:

1. No-tape: handle-bar bare; tester did not assist.
2. No-tape hold: handle-bar bare; tester grasped subject's hands.
3. Tape: handle-bar covered with one layer of tape; tester did not assist.
4. Tape-hold: handle-bar covered with one layer of tape; tester grasped subject's hands.
5. Straps: handle-bar bare; one-inch wide leather strap in each hand wrapped around bar and attached to the hands.

The means for the five techniques, in order of above, were 384.66, 364.66, 421.33, 431.33, and 458.00 pounds respectively. In other words, there was an increase in the recorded back strength as friction increased between the hands and bar, with the exception that the no-tape mean exceeded the no-tape-hold mean by twenty pounds. Analysis of variance showed significant differences beyond the 0.02 level between means.

The writers concluded that maximum back strength, using the back dynamometer, can only be determined if the hands are securely fastened to the handle-bar while performing the test, so that testing for maximum back strength should not be done without a taped handle-bar or without straps as here employed; and that holding the subject's hands during the test does not necessarily result in a higher recorded score.

Reliability, Validity, Objectivity, and Correlation

Brown (2) in his review of selected studies found the range of reliability for back-lift strength to be from 0.62 to 0.97. In his particular study on 208 freshmen at Southern Methodist University, he found the reliability to be 0.855 and the standard deviation to be ± 0.22 . Fox (15) found similar results for freshmen (0.87) with reliabilities of 0.93 for sophomores and 0.93 for juniors.

Whitley and Smith (31) tested sixty college men at the University of California on four measurements of lateral adductive arm strength and found the reliability coefficient to be higher when the average of several available trials was used instead of the best score (0.66 versus 0.57). Henry (16) agrees with Whitley and Smith that in strength tests the individual score should consist of the average of several trials.

With regard to validity, since large muscle activity (for example, back-extensor muscles) improves general fitness, and since physiologists tell us that by using the muscles they are strengthened, a measure of the strength status of the muscles should also be a measure of the physical fitness of the individual. With the relationship between strength and physical fitness understood, the validity of the P.F.I. as a measure of physical fitness may be considered. As a score of one hundred is average, deviations from this figure should be classified as physically

superior or inferior. Individuals with indices above one hundred should have greater physical capacity, and vice versa. The reasonableness of this statement is apparent; there is published experimental evidence to support it (6), (23), (25).

A comparison of scores obtained when the P.F.I. was given to non-oriented subjects by inexperienced testers with results when the subjects were oriented and the testers experienced was made by Mathews (24) on forty-one seniors at Springfield College. The resultant objectivity coefficient for the back lift was 0.74 as compared to the established coefficient of 0.88. Even though the back lift seems easy to administer, experienced testers and subjects obtain more valid results. The difference above is significant beyond the 0.01 level of confidence. The reliability, however, has been proven by many studies since 1925, and if the back-lift item is correctly administered and test directions followed carefully, the objectivity values should reach the same level as the reliability values (23).

In a study by Clarke and Carter (10) on 356 boys in the Medford, Oregon, public schools, various correlations with back lift were obtained at the elementary, junior, and senior levels. Since the grip is important in the back-lift test, the correlation between back-lift score and grip strength seems pertinent. Clarke and Carter found the back lift to correlate with right-hand grip strength 0.56 at the elementary level, 0.84 at the junior level, and 0.60 at the senior level. The figures for correlation between back lift and strength index were 0.67, 0.81, and 0.74 respectively; and back lift with the P.F.I. were 0.41, 0.35, and 0.20 respectively. Seymour (27) obtained similar results on Massachusetts senior high school boys. Correlations of back lift with right-grip

strength, S.I., and P.F.I. were 0.48, 0.70, and 0.38 respectively, as compared to 0.60, 0.74, and 0.20 in Clarke and Carter's study. In Brown's (2) study, back strength correlated 0.528 with a final criterion composed of the average T-scores on twenty-six elements, one of which was back strength.

Comparison of Instruments for Testing

Since the origination of the P.F.I. in 1925, various instruments involved in strength testing have been developed in addition to the original back dynamometer. Such devices as the cable tensiometer and strain-guage have thrown new light into the problem of strength testing. Kennedy (21) advocates substituting the tensiometer for the dynamometer in back-lift testing. Using college males at the University of Oregon, he found the objectivity coefficient for the back lift with the tensiometer to be 0.90 which compared favorably with the test-retest reliability estimate of 0.88 using the dynamometer (6). The same subjects were tested on both the tensiometer and the dynamometer giving a correlation of 0.92 between instruments. The tensiometer yielded slightly higher back-lift scores and a slightly greater dispersion of scores than did the dynamometer. However, this was not significant at the 0.05 level.

Clarke (7) is in full agreement with Kennedy with regard to the tensiometer. Clarke found, as reflected by objectivity coefficients, that the cable-tension technique had the greatest precision for strength testing. It was also the most stable and generally useful of the instruments. Using this cable-tension technique, Clarke (8) has his own method of testing extension of the back, which he terms "trunk extension". The testing is done on a table with a twenty-inch by seven-inch cut lengthwise in the centre to permit the attachment of a pulling assembly below

the subject. A trunk strap is placed around the subject's back and is hooked to the pulling assembly below the table, with the subject in a prone position with hands folded over the small of the back. On the command the subject extends his trunk maximally and the score is recorded. For sixty-four non-disabled male students at Springfield College, the mean score was 234.66 pounds. For this method the results are much lower than they are for the back lift. Hutchins (19) has used Clarke's method on female university students at the University of Oregon where she obtained a mean of 55.83 pounds.

Electrogoniometry

Karpovich and Karpovich (20) have developed an electrogoniometer to study joint movement. Basically, the electrogoniometer consists of a round rheostat with two shafts attached. The electrogoniometer is attached to the joint while the round rheostat rests on the joint itself. A more detailed description of the electrogoniometer is given in Chapter III.

Klissouras and Karpovich (22) in their electrogoniometric study of jumping events used an electrogoniometer on the hip joint. For its placement, straight lines were drawn from the lateral epicondyle of the femur to the uppermost portion of the superior border of the greater trochanter and from here to the iliac crest, so that the arms of the chassis were placed over the drawn lines and the centre of the elgon over the greater trochanter (axis of hip-joint rotation in the sagittal plane). The elgon measured the angle between the line drawn on the thigh up to the trochanter and the one drawn from the trochanter to the iliac crest. Thus only hip flexion and extension were recorded.

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CHAPTER III

METHODS AND PROCEDURES

Subjects

Twenty-four male student volunteers in attendance at The University of Alberta were used as subjects. Each subject was randomly assigned to one of twenty-four different testing orders. The subjects were enrolled in the Faculties of Agriculture, Education, Graduate Studies, Medicine, Physical Education, and Science. The subjects ranged in age from twenty-one to thirty-five.

Experimental Design

A treatments by subjects design was used where each subject was tested on four different days using a different testing method each day. Subjects were tested on consecutive days and at approximately the same time each day. To eliminate any activity that might prevent a maximal lift, the subjects were asked to avoid any strenuous exercise prior to their test performance. Three different trials were allowed on each test with a one minute rest interval between each trial. All scores were recorded as well as the change in hip angle throughout the back lift and the angle at which the back-lift score (maximal lift) occurred.

Anthropometrical Data

The following anthropometrical data was collected from each subject: age (years and months); height (inches); weight (pounds).

Procedures for Administering the Tests

Four different tests were administered to each subject which were simply known as Tests A, B, C, and D. Test A, as shown in Figure 1,



FIGURE 1

SUBJECT PERFORMING TEST A USING THE TRADITIONAL BAR, WITH NO RESTRICTION OF BACKWARD LUNGING



FIGURE 2

SUBJECT PERFORMING TEST B USING THE TRADITIONAL BAR, WITH BACKWARD LUNGING PREVENTED BY THE VERTICAL BOARD



FIGURE 3

SUBJECT PERFORMING TEST C USING THE EXPERIMENTAL SHOULDER HARNESS AND SELF-CONTAINED BAR WITHOUT HANDS
WITH NO RESTRICTION OF BACKWARD LUNGING



FIGURE 4

SUBJECT PERFORMING TEST D USING THE EXPERIMENTAL SHOULDER HARNESS AND SELF-CONTAINED BAR WITHOUT HANDS
WITH BACKWARD LUNGING PREVENTED BY THE VERTICAL BOARD

involved the traditional bar and experimental back-lift dynamometer with no restriction of backward lunging. Test B, shown in Figure 2, was the same as Test A except a vertical board on the back-lift dynamometer was used to prevent backward lunging. Test C is shown in Figure 3 and involved the use of the experimental shoulder harness and self-contained bar, and the experimental back-lift dynamometer with no restriction of backward lunging. The subjects were not allowed to use their arms or hands in any way on Test C, but were instructed to let them hang at their sides. Test D, shown in Figure 4, was identical to Test C with the exception of the vertical board to prevent backward lunging.

In addition, the electrogoniometer was attached to the left hip of each subject for each test to measure changes in hip angle throughout the test, and the angle at which the back-lift score (maximum lift) occurred. The electrogoniometer was placed on the lateral side of the left hip so that the rheostat rested on the midpoint of the greater trochanter of the femur with the shafts connecting with the iliac crest and the midpoint of the lateral epicondyle (1). The electrogoniometer was secured with adhesive tape.

In Tests A and B the bar was taped but the tester did not hold the subject's hands on the bar. In these same two tests the height of the bar was derived as in the traditional method. In Tests C and D the subject assumed the traditional starting position and the cable was attached directly to the self-contained bar of the shoulder harness which had been adjusted so that this bar was at the level of the manubrium of the subject. The traditional bar was then removed.

In all tests the feet were placed in such a way that the malleoli of the ankle joint were opposite the base of the cable and six inches apart.

In each trial for every test the starting position was held for five seconds. The command to lift was the same in the four tests--the subject was asked to lift straight up by extending his back and keeping his legs straight. The subjects were told that it was important that they lift as hard as possible. Each back lift (trial), all of which were administered by the writer, took approximately three seconds with a one minute rest between trials.

Experimental Apparatus

Back-Lift Dynamometer. The experimental back-lift dynamometer, illustrated in Figure 5, consisted of a two-horsepower electric three-phase motor connected by means of a flexible coupling to a Vickers eighteen gallon-per-minute vane pump, to a positive filter, to a directional control valve which enabled a double-acting hydraulic cylinder to move forwards or backwards or stop. The hydraulic cylinder had a three-inch diameter and a thirty-inch stroke. Connected to the cylinder was a cylinder rod and connected to this was a three-thousand pound capacity cable. The cable passed over two ball-bearing pulleys so as to pass out and up from the machine at a point directly between the subject's feet and in front of the subject. This cable was connected to a load cell which was connected by means of a chain link to the traditional bar in Tests A and B. In Tests C and D, the load cell was connected to the self-contained bar of the experimental shoulder harness by means of a short length of cable. The entire system was raised or lowered for each subject by the hydraulic mechanism of the experimental back-lift dynamometer.

Directly behind the subject, in Tests B and D, was placed a solid plywood hip support (vertical board) so that the subject was unable to



FIGURE 5

EXPERIMENTAL BACK-LIFT DYNAMOMETER

lunge backwards during each lift.

Traditional Bar. A bar used for the traditional back-lift test was used for Tests A and B. This bar was taped with adhesive tape.

Experimental Shoulder Harness. The specially-designed shoulder harness, seen in Figure 6, consisted of two nylon car seat-belts which looped over the subject's shoulders (one over each shoulder). Into the loops at the ends of the seat-belts was inserted a steel bar similar to the traditional bar except that its hook was parallel to the bar itself to avoid discomfort to the subject's chest in Tests C and D. The bar was adjusted to the height of the subject's manubrium by means of closing the car seat-buckles and adjusting the belts until the bar was at the desired height and level. Adjustable canvas connecting straps tied across the back of the subject prevented the seat-belts from sliding laterally on the subject's shoulders. Some friction was also produced by the shoulder pads through and on top of which passed the seat-belts over the shoulders. In this way, the bar and harness was secured to the subject.

The construction of the experimental shoulder harness facilitated its application to and removal from the subject.

Load Cell and Dynograph. The load cell used was a 1000 pound capacity load cell, model UG31 tension type from BLH Electronics. Power to and from the load cell was provided through a Beckman Type RS Dynograph with two channels for recording. Signals from the load cell were received by and recorded on the dynograph which was calibrated to move one millimeter for every ten pounds of tension on the load cell. Signals from the electrogoniometer were recorded on the other channel of the dynograph which was calibrated to move two millimeters for one degree of

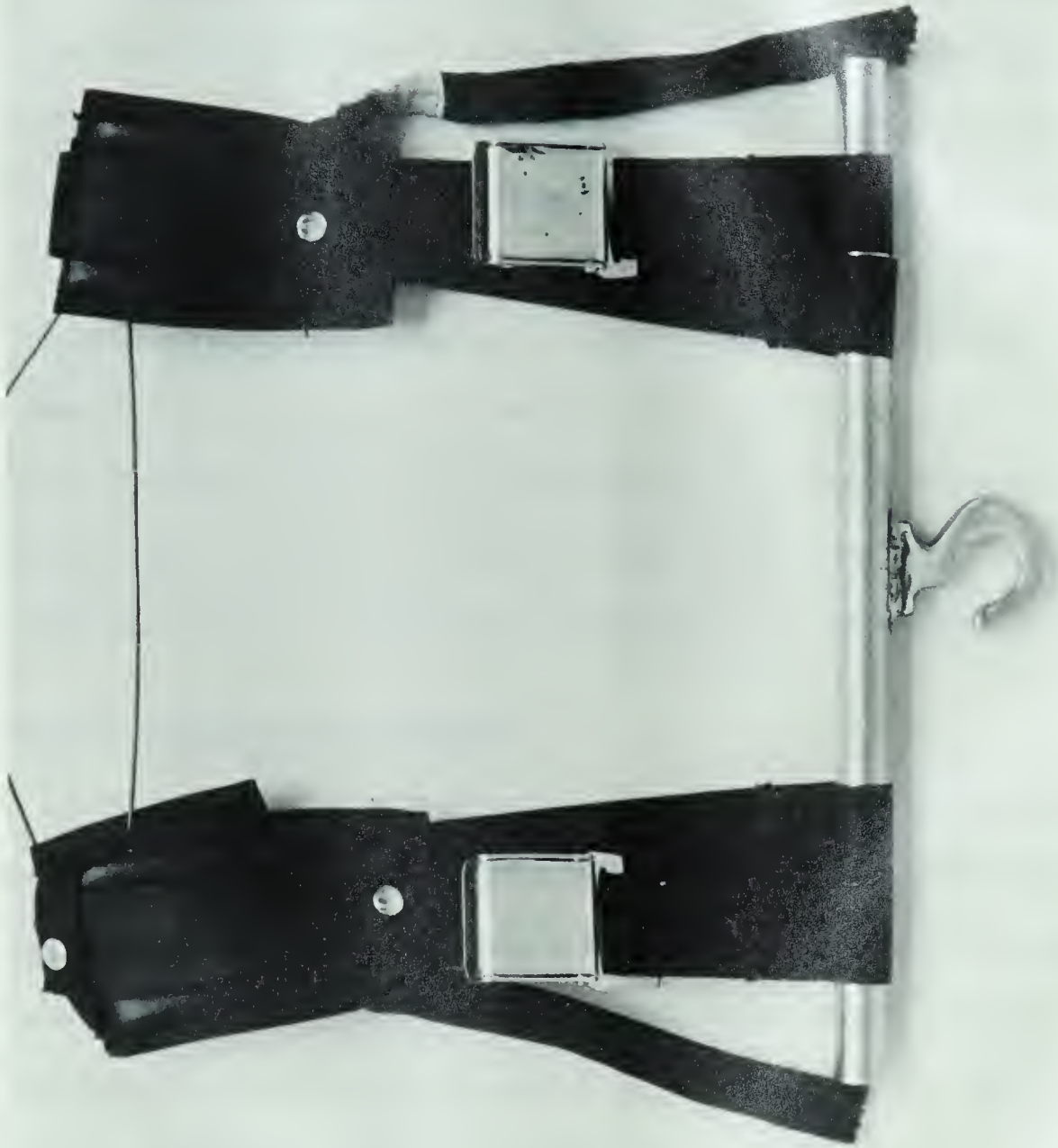


FIGURE 6

EXPERIMENTAL SHOULDER HARNESS WITH SELF-CONTAINED BAR

change in hip angle.

Sargent Recorder (Model SR). The signals received on the dynograph were simultaneously amplified on a Sargent Recorder. This machine was calibrated to 1000 pounds pull and accuracy to within five pounds was achieved.

Electrogoniometer. The electrogoniometer consisted of a rheostat with two plastic shafts. The rheostat portion of the goniometer was placed over the midpoint of the greater trochanter of the femur with the two shafts connecting with the iliac crest and the midpoint of the lateral epicondyle. The electrogoniometer was connected by a wire to a meter, which in turn was connected to the dynograph. Power for the electrogoniometer was supplied by a small battery. For calibration, a protractor was attached to the electrogoniometer with adhesive tape so that one shaft was immobilized while the other shaft was free to move causing a change in angle. Calibration procedures are described in Appendix F.

Calibration of the Apparatus

The load cell, dynograph, and Sargent recorder were calibrated by comparing the indicated deflection on the graphs with known weights added to the load cell in five-pound intervals. Accuracy to within ten pounds was achieved on the dynograph, whereas accuracy to within five pounds was achieved on the Sargent recorder up to 1000 pounds. Linearity of the load cell measurements was confirmed.

Statistical Treatment

Reliability coefficients were computed using analysis of variance to estimate the reliability of measurements. The standard error of measurement was computed for each test method. The significance of the dif-

ferences among the means of the maximum scores of the four tests and among the means of the mean scores of trials two and three of the four tests was computed using an analysis of variance technique. Correlations between lift score and the hip angle at which the lift score (maximum lift) occurred were determined. Adjustments were made to the scores on the basis of the above factor. The significance of the differences among the means of the adjusted maximum scores of the four tests and among the means of the adjusted mean scores of trials two and three of the four tests was computed using an analysis of variance technique.

Pilot Study

A pilot study was carried out on eight graduate students in the Faculty of Physical Education at The University of Alberta employing the same four tests used in this study to assess the effectiveness of the experimental shoulder harness technique with the electrogoniometer attached to the hip joint.

Several types of shoulder harness were tried in the pilot study from which the experimental shoulder harness used in this study was selected.

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CHAPTER IV

RESULTS AND DISCUSSION

Analysis of Data

The analysis of data is presented in the following order: reliability coefficients; standard error of measurement; means of trials by tests; analysis of variance using maximum scores; analysis of variance using the mean scores of trials two and three; regression analysis of score with hip angle where the score occurred; analysis of variance using adjusted maximum scores; and analysis of variance using the adjusted mean scores of trials two and three.

The following reliability coefficients were determined on all subjects for each test using analysis of variance to estimate the reliability of measurements (9: 124-131).

TABLE I
RELIABILITY COEFFICIENTS

Test Method	Reliability Coefficients
A	0.95
B	0.98
C	0.94
D	0.96

The reliability coefficients are test-retest correlations and make no indications as to the precision of an individual's score. The reliabilities for an individual's score on each test are given in Table II.

The standard error of measurement as per (8: 183) was used to estimate the standard deviation of the series of measurements on the same individual. The reliability coefficients from Table I and the standard deviations from Table IV were employed to compute the standard error of



measurement for each test. Table III shows the standard error of measurement for each test.

TABLE II
RELIABILITY COEFFICIENTS

Test Method	Reliability Coefficients
A	0.87
B	0.94
C	0.85
D	0.89

It can be seen from Table III that scores using Test A can be expected to vary in approximately sixty-eight per cent of the cases by ± 17.15 pounds, scores on Test B ± 11.93 pounds, scores on Test C ± 24.27 pounds, and scores on Test D ± 23.58 pounds. The most accurate

TABLE III
STANDARD ERROR OF MEASUREMENT - SUMMARY

Test Method	Sm
A	17.15
B	11.93
C	24.27
D	23.58

results are obtained from the test having the least standard error of measurement, in this case Test B.

Table IV displays the means of all trials for each test and is based on the raw data as presented in Appendix A.

The only distinct pattern observed in Table IV is that the descending order for the General Means from Test A to Test D directly parallels the ascending order of the General Standard Deviations from Test A to Test D.

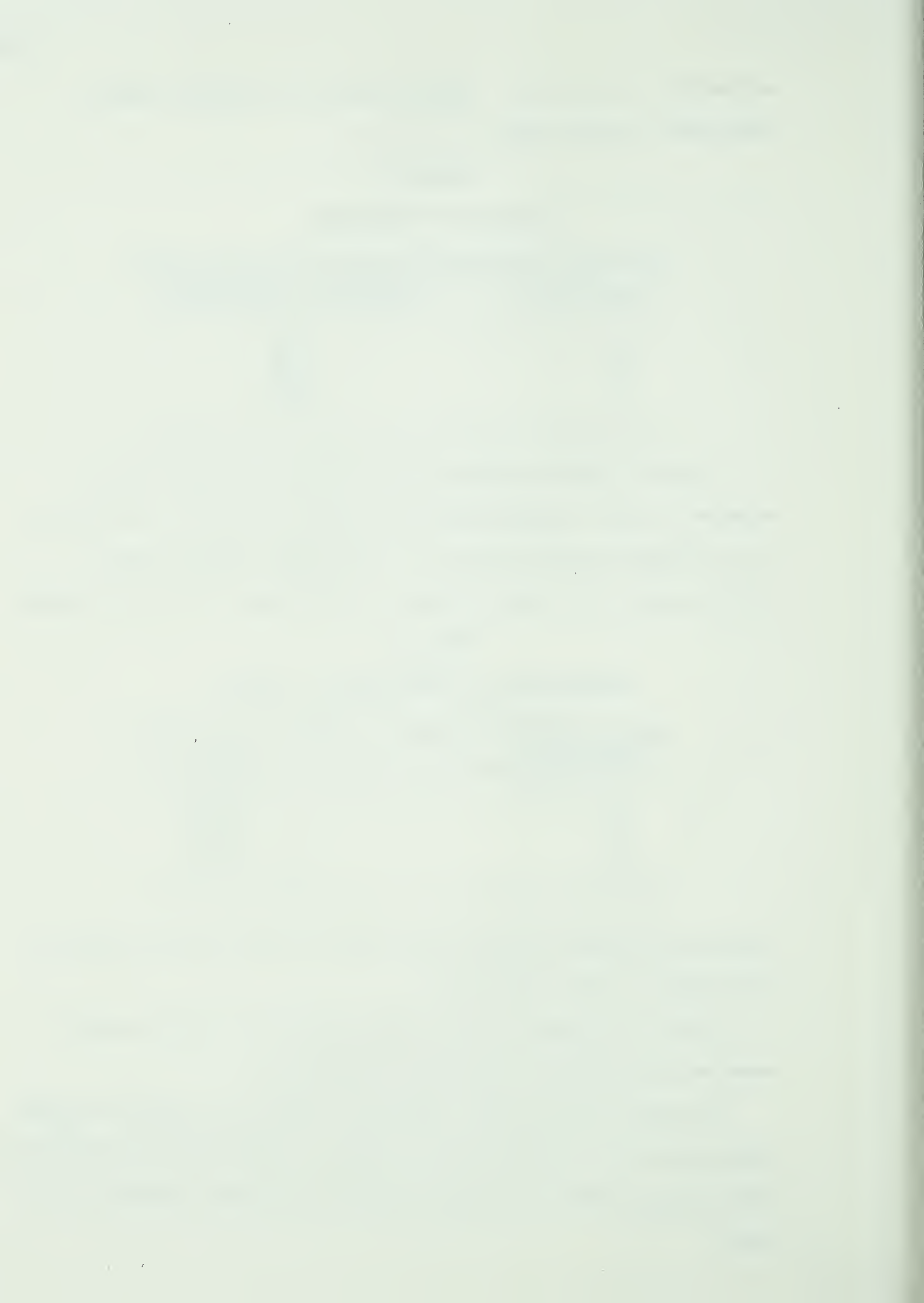


TABLE IV
MEANS OF TRIALS BY TESTS

		Test Method			
		A	B	C	D
Trials	1	335.42	338.33	317.08	293.96
	2	352.29	349.58	351.88	321.25
	3	351.25	343.33	359.38	349.17
General Means		346.32	343.74	342.78	321.17
General 6		78.50	83.39	101.58	116.91

Analyses of variance using maximum scores and mean scores of trials two and three were carried out to determine whether observed differences in Table IV were significant. The means for maximum scores are presented in Table V.

TABLE V
MAXIMUM SCORE MEANS

		Test Method			
		A	B	C	D
Means		362.29	359.79	374.17	351.46

Here the descending order of means is Test C, Test A, Test B, and Test D. The significance of the observed differences among means in Table V was tested by analysis of variance using maximum scores. The results are displayed in Table VI.

The F value for tests as determined by analysis of variance using maximum back-lift strength scores was not significant.

TABLE VI
ANALYSIS OF VARIANCE - SUMMARY
MAXIMUM SCORES

Source	Sums of Squares	df	Mean Squares	F
Between Subjects	825,034.00	23	35,871.04	
Within Subjects	157,087.00	72	2,181.76	
Tests	6,339.00	3	2,113.00	0.97
Residual	150,748.00	69	2,184.75	
Total	982,121.00	95		

$$F = \frac{df}{3,69} \begin{matrix} .05 \\ 2.74 \end{matrix} \begin{matrix} .01 \\ 4.08 \end{matrix} \quad p < .5$$

In Table VII, the descending order of means is again Test C, Test A, Test B, and Test D. The significance of the observed differences among

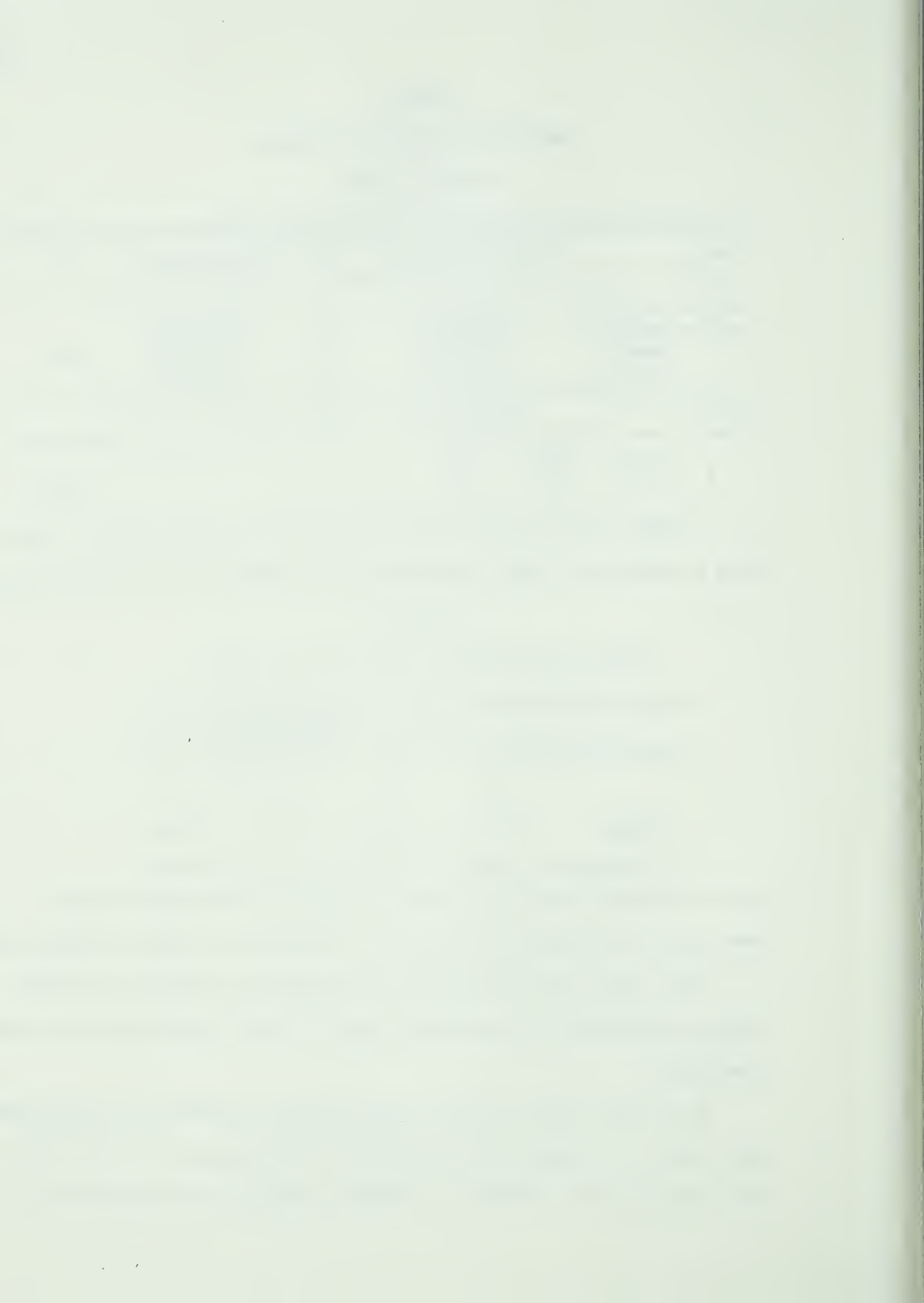
TABLE VII
MEAN OF SCORE MEANS OF TRIALS TWO AND THREE

	Test Method			
	A	B	C	D
Means	351.77	346.46	355.63	335.21

means in Table VII was also tested by analysis of variance using the mean scores of trials two and three. The results are found in Table VIII.

Again, the F value for tests as determined by analysis of variance using the mean back-lift strength scores of trials two and three was not significant.

To see what portion of the sum of squares of back-lift strength measure could be accounted for by variation in the hip angle at which the back-lift score was attained, a regression analysis was carried out on



each test to eliminate the sum of squares due to variation in the hip angle where the back-lift score was attained.

TABLE VIII
ANALYSIS OF VARIANCE - SUMMARY
MEAN SCORES OF TRIALS TWO AND THREE

Source	Sums of Squares	df	Mean Squares	F
Between Subjects	767,755.00	23	33,380.65	
Within Subjects	152,889.00	72	2,123.46	
Tests	5,669.00	3	1,889.67	0.89
Residual	147,220.00	69	2,133.62	
Total	920,644.00	95		

	df	.05	.01	
F =	3,69	2.74	4.08	p < .5

The value of the sum of squares for the angle at which the back-lift score was attained was determined from the fraction:

$$\frac{(\sum xy)^2}{\sum y^2}$$

where $\sum xy$ = the sum of the cross products of the deviations from the mean of the back-lift scores and the angles at which the scores were attained.

$\sum y^2$ = the sum of squares of the deviations from the mean of the angles at which the scores were attained.

This value is seen in Table IX as Regression, and with the remainder (Unexplained) makes up the total sum of the squares of the scores for each test. Table IX displays the regression analysis for each test.

In Table IX a significant proportion of the total variance can be accounted for by the variance due to the angle of the hip at which the scores occurred in Test B, Test C, and Test D. In Test B this relationship is beyond the .01 level of confidence.

These relationships were determined also as correlation coefficients

TABLE IX
REGRESSION ANALYSIS OF SCORES AND ANGLES
WHERE SCORES OCCURRED USING ALL SCORES

Test Method	Source	df	Sums of Squares	Mean Squares	F
A	Regression	1	316.78	316.78	.05
	Unexplained	70	437,282.88	6,246.90	
	Total	71	437,599.66	6,163.38	
B	Regression	1	96,802.10	96,802.10	17.07**
	Unexplained	70	396,885.40	5,669.79	
	Total	71	493,687.50	6,953.35	
C	Regression	1	53,351.65	53,351.65	5.50*
	Unexplained	70	679,192.80	9,702.75	
	Total	71	732,544.45	10,317.53	
D	Regression	1	53,440.61	53,440.61	4.08*
	Unexplained	70	916,981.27	13,099.73	
	Total	71	970,421.88	13,667.91	

F = df .05 .01 * significant at .05 level
 1,70 3.98 7.01 ** significant at .01 level

between the two variables (score and corresponding hip angle) by obtaining the value of Regression Sum of Squares divided by the Total Sum of Squares and taking the square root of that value for each test. These correlation coefficients appear in Table X along with the proportion of the variance of the strength scores that can be predicted from the variance of the angle of the hip where the scores occurred.

In other words 0.09 per cent of the variance of back-lift scores can

be predicted from the variance of the angle of the hip where the scores occurred for Test A, 19.36 per cent for Test B, 7.29 per cent for Test C, and 5.29 per cent for Test D.

Standard deviations were calculated from Table IX by taking the square root of the Unexplained Mean Square. The calculated standard deviations were combined with the reliability coefficients from Table I

TABLE X
CORRELATION COEFFICIENTS BETWEEN BACK-LIFT SCORE
AND HIP ANGLE WHERE SCORE OCCURRED

Test Method	r	$r^2 \times 100$
A	- 0.03	0.09
B	0.44	19.36
C	0.27	7.29
D	0.23	5.29

to determine the new standard errors of measurement for each test with the angle relationship taken into consideration. The adjusted standard errors of measurement are displayed in Table XI and were derived as per Thorndike and Hagen (8: 183).

TABLE XI
ADJUSTED STANDARD ERROR OF MEASUREMENT - SUMMARY

Test Method	Sm
A	17.26
B	10.78
C	23.53
D	23.09

Comparing the results of Table XI with those of Table III, it is found that accounting for the variation in hip angle at which the back-lift scores occurred reduced the standard errors of measurement for each

test except Test A where there was a negative correlation between back-lift scores and the angles at which they occurred (Table X).

To see if the relationships between back-lift scores and the angles at which they occurred had obscured any differences between scores on each test, an adjustment was made on the scores of each test using a method according to Elashoff (5: 383-401) which employed a regression coefficient for each test. The regression coefficient was derived for each test from the fraction:

$$\frac{\sum xy}{\sum y^2}$$

where $\sum xy$ = the sum of the cross products of the deviations from the mean of the back-lift scores and the angles at which the scores were attained.

$\sum y^2$ = the sum of squares of the deviations from the mean of the angles at which the scores were attained.

The regression coefficient for Test A was -0.3155 , for Test B 4.58 , for Test C 3.41 , and for Test D 3.63 .

Analyses of variance using maximum scores and mean scores of trials two and three were carried out on the adjusted scores. The means for the adjusted maximum scores are presented in Table XII.

TABLE XII
MAXIMUM SCORE MEANS - ADJUSTED

	Test Method			
	A	B	C	D
Means	362.28	361.33	372.34	349.97

Here again, in Table XII, the descending order of means is still Test C, Test A, Test B, and Test D as was the case in Table V. As compared to Table V, the mean for Test A has remained approximately the same;

the mean for Test B has been raised approximately two pounds; and the means for Tests C and D each lowered approximately two pounds. The significance of the observed differences among means in Table XII was tested by analysis of variance using adjusted maximum scores. The results are displayed in Table XIII.

TABLE XIII
ANALYSIS OF VARIANCE - SUMMARY
MAXIMUM SCORES - ADJUSTED

Source	Sums of Squares	df	Mean Squares	F
Between Subjects	726,919.00	23	31,605.17	
Within Subjects	172,982.00	72	2,402.53	
Tests	5,976.00	3	1,992.00	0.82
Residual	167,006.00	69	2,420.38	
Total	899,901.00	95		

	df	.05	.01	
F =	3,69	2.74	4.08	p < .5

The F value for tests as determined by analysis of variance using the adjusted maximum back-lift strength scores was not significant.

TABLE XIV
MEAN OF SCORE MEANS OF TRIALS TWO AND THREE - ADJUSTED

	Test Method			
	A	B	C	D
Means	351.80	346.23	353.51	333.98

In Table XIV, the descending order of means using the adjusted means of trials two and three is also Test C, Test A, Test B, and Test D, as in Table VII. Comparing Table XIV to Table VII, the means for Tests A

and B have both remained approximately the same; and the means for Tests C and D have each decreased approximately two pounds. The analysis of variance summary for the significance of the observed differences among means in Table XIV is found in Table XV.

TABLE XV
ANALYSIS OF VARIANCE - SUMMARY
MEAN SCORES OF TRIALS TWO AND THREE - ADJUSTED

Source	Sums of Squares	df	Mean Squares	F
Between Subjects	692,967.00	23	30,129.00	
Within Subjects	163,008.00	72	2,264.00	
Tests	5,576.00	3	1,858.67	0.81
Residual	157,432.00	69	2,281.62	
Total	855,975.00	95		

	df	.05	.01	
F =	3,69	2.74	4.08	p < .5

Similarly, the F value for tests as determined by analysis of variance using the adjusted mean back-lift strength scores of trials two and three was not significant.

The mean range of hip angle was computed for each test using the means of trials two and three. These mean hip angle ranges are shown in Table XVI for each test and are listed as absolute values.

The differences among means that can be observed in the data of Table XVI seem to be of two kinds. Firstly, the larger means appear for Test C and Test D where the experimental shoulder harness and self-contained bar was used. The smaller means appear for Test A and Test B. Both of these tests used the traditional bar. Secondly, there appears to be a difference between the angle changes for Test A and Test B, as well as for Test C and Test D. Test A and Test C, where there was no

restriction of lunging, have the greater mean changes in angle than their respective counterparts, Test B and Test D, where lunging was prevented.

TABLE XVI
HIP ANGLE RANGE MEANS FOR TESTS

Test Method	Range Mean (Degrees)
A	2.34
B	2.10
C	6.06
D	4.33

Also computed for each test was the mean angle at which the back-lift scores occurred (i.e. point of maximal lift) using the means of trials two and three. These mean maximum lift angles are displayed in Table XVII.

TABLE XVII
MEAN MAXIMAL LIFT ANGLES FOR TESTS

Test Method	Mean Angle (Degrees)
A	161.97
B	162.22
C	163.21
D	163.42

The larger means appear for Tests C and D where the experimental shoulder harness and self-contained bar was used. This is verified by the fact that there was a greater (not more than four degrees) range of hip angle using the experimental shoulder harness and self-contained bar as was observed in Table XVI.

An attempt was made to analyse the performance of all individuals on each of the twelve trials in the order that each subject took the

tests in order to compare their performance over the four test sessions. These means are presented in Table XVIII.

TABLE XVIII
MEAN SCORES FOR EACH TRIAL FOR ALL SUBJECTS
IN THE ORDER THAT EACH SUBJECT TOOK THE TESTS

Trial	Mean
1	336.67
2	358.96
3	355.63
4	332.29
5	357.29
6	365.00
7	311.04
8	329.38
9	343.75
10	304.79
11	329.38
12	338.75

Table XVIII shows that the means of the twelve trials for each subject in the order that the subject took the tests declined after the middle trial (Trial 6) of testing. It also demonstrates the fact that the first trial means of each test were always of lesser magnitude than the means of the second and third trials.

Discussion

Tests. The reliability coefficients ranged from 0.94 to 0.98. The reliability coefficients of Test A and Test B where the traditional bar was used are supported by previous research findings (1), (2), (6), (7). These two reliability coefficients were 0.95 and 0.98 respectively. Tests C and D, which are the tests involving the use of the experimental

shoulder harness, had reliability coefficients of 0.94 and 0.96 respectively.

Tests A and B, where the traditional bar was used, had the lowest standard errors of measurement. The least standard error of measurement was obtained for Test B. This appears to be due to the fact that lunging was prevented by the vertical board in Test B. Tests C and D had the highest standard errors of measurement. This appears to be attributed to the use of the new shoulder harness and self-contained bar along with the fact that the subjects had to get used to the idea of lifting without using their arms. However, no slippage of the harness was apparent and the subjects reported the harness as being very comfortable. Test D had a lower standard error of measurement which again appeared to be due to the prevention of lunging. Test B was the most reliable of the four tests and had the least standard error of measurement.

The maximum back-lift score of three trials was used in the statistical analysis of data because maximum strength scores are commonly recorded in the administration of the P.F.I. test battery. The mean of trials two and three was used in the statistical analysis instead of the average of three trials since not all subjects were familiar with the four test methods. This was especially the case in Tests C and D (see Table IV) where the new shoulder harness and self-contained bar was used. The idea of wearing the new piece of equipment along with the idea of lifting without the use of the arms and hands was foreign to most subjects. This probably explains why the means of trial one in Test C and D were significantly lower than the means of the second and third trials. These differences were significant at the 0.01 level of confidence in both cases. For Tests A and B the corresponding probabilities were $p < .08$ and $p < .17$ re-

spectively. In this light, using the mean of trials two and three was thought to give a more realistic representation of the data than the average of three trials as is usually the case (2: 171). Consequently trial one was treated as a practice trial.

No significant differences were found between the four testing methods. This lends one to disagree with the hypothesis that the hands "give out" before the back does and that the hands must be securely fastened to the bar while performing back-lift tests.

The descending order of means in the statistical analysis was Test C, Test A, Test B, and Test D for maximum scores and mean scores of trials two and three.

Hip Angle. Significant relationships were found between back-lift score and the angle where the back-lift score occurred in Test B, Test C, and Test D. In Test A, this relationship was insignificant and negative. This appeared to be due to the lunging factor, since a subject could conceivably exert force on the loadcell without any alteration in his hip angle. Test C scores were significantly related to the angles at which they occurred since a greater range of hip angle was found (see Table XVI) than in Test A, and a greater arching of the back was observed with the use of the new shoulder harness where the use of hands and arms was forbidden. In Tests B and D, one would expect hip angle to be related to back-lift score because the subject could only pull upwards with no backward component of force. In Test B the greatest relationship existed.

Errors inherent as far as hip angle is concerned were difficult to measure since lifting mechanics and starting hip angles were different for each subject as derived from the Rogers' P.F.I. item, Back-Lift. The mechanics of the Back-Lift were further effected by the unfamiliarity of lifting without the use of hands and arms.

Adjusting the scores on each test for the effect of the angles at which maximum back lift occurred reduced the standard errors of measurement by reducing the standard deviations of Test B, Test C, and Test D. Since the relationship between back-lift score and corresponding hip angle was negative in Test A, the adjustment of scores caused the standard error of measurement to increase slightly (see Tables III and XI). However, analysis of variance using adjusted scores yielded no significant differences between the means of the four testing methods.

As displayed in Table XVI, the ranges in hip angle for the four tests were slight with the maximum difference between them being 3.96 degrees. The ranges are recorded as absolute values because in Tests A and B for approximately one-half the subjects the range was negative. This appeared to be caused by throwing back the shoulders or bending the elbows slightly, or a combination of these. Each of these would cause the subject's hip angle to decrease with respect to the horizontal. In all but one of the cases in Tests C and D the range of hip angle was positive. This was probably due to the fact that in these two tests where the experimental shoulder harness was employed the extent of throwing back the shoulders was reduced and the bending of elbows eliminated. The smaller absolute ranges were obtained for Test A and Test B with the use of the traditional bar. The larger absolute ranges were obtained for Test C and Test D. In these two tests the experimental shoulder harness was used accompanied by a greater extension at the hip joint. Test A and Test C, where there was no restriction of lunging, had greater mean changes in hip angle than did Test B and Test D where lunging was prevented.

The mean maximal lift angles, listed in Table XVII, are supported by previous research (3), (4). The smaller means were obtained for Test A

and Test B; the larger means were obtained for Test C and Test D. This was also the case with the corresponding ranges in hip angle. The mean maximal lift angles were smaller for Test A and Test B where the shoulders could be thrown back or the elbows bent slightly. Each of these two factors would reduce the degree to which a subject's back could straighten. In Tests C and D, where the throwing back of the shoulders was reduced and the possibility of slight bending at the elbows eliminated by means of the shoulder harness, a greater extension at the hip was possible.'

Summary. No significant differences were found among the four tests when the maximum scores or the mean scores of trials two and three were used in the analysis of variance.

Although the angle of the hip at which maximum lift occurred was significantly related to the back-lift score in Test B, Test C, and Test D, no significant differences were obtained among the four tests when the maximum scores or mean scores of trials two and three adjusted for angle effect were used in the analysis of variance.

Adjusting the scores reduced the standard errors of measurement of Test B, Test C, and Test D. The standard error of measurement for Test A did not change significantly.

The means always descended from high to low in the order of Test C, Test A, Test B, and Test D, as was the case in the pilot study.

The range in hip angle was slight for all tests with the range in hip angle range means being only 3.96 degrees. However the range was somewhat higher for Test C and Test D where the experimental shoulder harness and self-contained bar was used. Similarly, the angle at which maximal back-lift occurred was somewhat higher for Test C and Test D. These results are also supported by the pilot project carried out prior

to the study.

The lower errors of measurement occurred with Test A and Test B where the traditional bar was used. Test B, where lunging was prevented, had the least standard error of measurement.

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CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to investigate differences in effective back-lift strength scores when the hands were allowed to grasp the bar and when a new shoulder harness with self-contained bar was used which eliminated the need for a subject to use his arms and hands. A sub-problem was to measure the change in hip angle and the angle at which the back-lift strength scores occurred.

Twenty-four male students in attendance at The University of Alberta volunteered their services as subjects. They were randomly assigned to twenty-four different testing orders so that no testing order was duplicated.

Each subject took four different back-lift strength tests and was allowed three trials on each. Test A involved the traditional bar and experimental back-lift dynamometer with no restriction of backward movement. Test B was the same as Test A with the exception that backward lunging was eliminated. Test C involved the use of the experimental shoulder harness and self-contained bar, and the experimental back-lift dynamometer with no restriction of backward lunging. The subjects were not allowed to use their arms or hands on Test C, but were instructed to let them hang at their sides. Test D was identical to Test C, only with the restriction of backward lunging in effect.

Analyses of variance using maximum scores and the means of trials two and three for both raw scores and scores adjusted for the effect of corresponding hip angles did not yield any significant F values for the test methods.

A greater range of hip angle was observed when the experimental shoulder harness and self-contained bar was used in Test C and Test D. Effective back-lift strength scores were obtained with the back at approximately twenty degrees from the vertical.

Conclusions

On the basis of the statistical analysis, the following conclusions are justifiable:

1. Differences among the four testing methods were not significant. When the relationship between back-lift strength scores and their corresponding hip angles was taken into consideration, there were no significant differences among the four testing methods.
2. The largest ranges in hip angle were found using the experimental shoulder harness and self-contained bar technique.
3. Ranges in hip angle were less when backward lunging was prevented.
4. Effective back-lift strength scores were obtained with the back making approximately a twenty-degree angle with the vertical.
5. Of the four tests, Test B was found to be the most reliable and had the least standard error of measurement, and is therefore thought to be the best test for measuring maximum back-lift strength.

Recommendation

It is recommended that the experimental shoulder harness and self-contained bar technique be further perfected in an attempt to reduce its standard error of measurement. Further comparisons with the traditional method could then be made.

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APPENDIX A

RAW DATA

TEST A

STRENGTH SCORES; INITIAL HIP ANGLES; AND MAXIMAL HIP ANGLES

Subject	Strength Score (Pounds)			Initial Hip Angle (Degrees)			Maximal Hip Angle (Degrees)		
	1	Trial 2	3	1	Trial 2	3	1	Trial 2	3
1	330	350	350	162.5	164.0	162.0	164.5	166.0	167.5
2	295	365	365	167.5	167.0	167.0	170.0	171.5	173.5
3	385	370	340	158.0	158.0	158.0	164.5	167.0	161.0
4	440	470	490	162.5	164.0	162.0	163.0	160.5	154.5
5	260	250	220	156.0	152.0	153.5	153.0	150.0	152.0
6	225	220	205	152.5	155.0	155.0	156.0	155.5	157.0
7	330	345	355	163.0	164.0	165.0	169.5	168.0	170.5
8	405	365	410	158.0	159.5	158.0	157.0	158.5	157.0
9	375	395	410	149.5	149.5	151.0	152.0	151.5	152.0
10	335	380	410	165.0	170.0	168.5	167.5	167.5	169.0
11	380	410	415	157.0	157.0	157.0	157.0	157.0	157.0
12	440	445	420	162.5	164.0	163.5	160.5	167.5	163.5
13	320	380	370	163.0	164.5	169.0	167.0	163.0	168.0
14	290	275	265	161.5	164.0	165.0	157.5	162.0	161.5
15	320	310	315	162.0	163.0	165.0	160.0	157.0	162.0
16	355	380	370	167.5	167.5	168.0	169.5	167.0	170.5
17	410	590	595	162.0	164.0	163.5	162.0	164.0	162.5
18	260	255	260	157.5	157.0	158.0	158.0	158.5	157.5
19	330	325	305	167.0	167.0	168.0	171.0	174.0	170.0
20	245	230	230	173.0	170.0	170.5	174.0	172.5	173.0
21	370	365	385	152.0	153.0	151.0	153.0	155.0	155.0
22	285	305	290	156.0	154.0	157.0	156.0	156.0	157.0
23	385	405	405	150.5	152.5	153.0	151.5	152.0	154.0
24	280	270	250	163.5	162.5	163.5	167.0	165.0	162.5

TEST B

STRENGTH SCORES; INITIAL HIP ANGLES; AND MAXIMAL HIP ANGLES

Subject	Strength Score (Pounds)			Initial Hip Angle (Degrees)			Maximal Hip Angle (Degrees)		
	1	Trial 2	3	1	Trial 2	3	1	Trial 2	3
1	325	370	385	161.5	162.0	162.0	161.5	164.0	164.5
2	325	345	280	170.5	172.5	170.0	175.0	176.5	176.0
3	350	355	375	161.5	162.5	163.0	167.0	167.0	165.0
4	465	485	460	170.0	169.0	170.0	176.0	175.0	174.5
5	235	265	285	151.0	152.5	153.5	152.0	152.0	152.5
6	230	210	215	148.5	152.0	150.0	142.5	149.5	147.5
7	375	385	335	161.5	162.5	160.5	162.5	161.0	166.5
8	375	370	380	150.0	151.0	150.0	149.5	148.0	149.5
9	365	430	425	162.5	163.0	161.0	160.0	163.0	162.5
10	350	395	345	172.5	173.0	174.5	172.5	171.0	174.0
11	325	365	405	158.0	153.0	156.5	156.5	156.0	156.0
12	430	435	425	163.0	163.0	160.0	160.0	167.5	158.5
13	345	395	375	161.0	161.0	160.0	161.0	157.5	159.0
14	225	235	205	161.5	164.0	163.5	162.0	164.0	162.0
15	320	315	305	160.0	166.5	165.0	155.0	158.5	166.0
16	390	395	375	167.5	166.0	168.0	169.0	164.0	170.0
17	595	565	565	165.5	165.0	165.0	170.5	164.0	165.5
18	255	260	265	153.5	153.5	153.5	154.0	154.0	155.0
19	300	280	305	168.5	169.0	170.0	168.0	167.0	168.0
20	230	215	215	151.0	147.0	151.0	152.5	148.5	152.0
21	340	300	340	165.5	164.0	165.0	167.0	168.5	166.0
22	345	380	350	171.0	171.0	169.5	172.0	172.5	170.5
23	365	375	365	159.0	156.0	159.0	163.0	160.5	161.0
24	260	265	260	163.0	162.0	162.0	160.5	154.0	161.0

TEST C

STRENGTH SCORES; INITIAL HIP ANGLES; AND MAXIMAL HIP ANGLES

Subject	Strength Score (Pounds)			Initial Hip Angle (Degrees)			Maximal Hip Angle (Degrees)		
	1	Trial 2	3	1	Trial 2	3	1	Trial 2	3
1	220	260	280	151.0	150.0	151.5	152.0	152.0	154.5
2	245	310	305	165.0	164.0	166.0	174.0	177.0	175.5
3	535	510	490	148.0	152.0	154.0	158.5	174.0	157.0
4	395	500	475	168.0	167.5	169.0	174.0	172.0	174.5
5	205	220	210	150.0	149.0	150.0	154.5	158.0	156.5
6	290	300	345	157.0	158.0	158.5	154.0	155.0	157.0
7	375	425	395	152.0	158.0	159.0	158.0	162.0	160.0
8	245	340	355	144.0	143.0	144.5	150.0	150.0	152.5
9	325	475	440	150.0	154.0	154.5	160.0	161.0	162.0
10	370	390	440	164.0	165.0	168.0	169.0	173.5	174.0
11	195	240	325	156.5	156.0	155.0	163.5	163.5	164.0
12	435	365	445	156.0	154.0	155.5	157.0	158.0	157.5
13	285	340	355	166.0	168.0	168.0	172.0	172.0	173.5
14	290	275	270	163.0	160.5	164.5	174.0	172.0	173.0
15	355	325	290	159.0	158.5	158.5	158.5	157.0	160.5
16	365	410	390	158.0	159.5	159.5	164.0	168.0	167.5
17	600	685	600	158.0	163.0	166.0	172.0	168.0	168.0
18	335	315	330	157.5	158.0	159.5	159.5	160.5	162.5
19	230	315	310	164.0	162.0	164.5	169.0	171.0	173.0
20	210	230	225	149.5	150.0	148.5	153.0	155.0	153.5
21	295	320	405	155.0	156.0	156.5	157.0	160.5	160.0
22	260	265	265	149.0	150.0	150.0	152.0	151.0	150.0
23	310	395	400	144.0	147.5	148.0	150.5	155.5	159.5
24	240	235	280	158.0	160.5	159.0	167.0	172.0	169.5

TEST D

STRENGTH SCORES; INITIAL HIP ANGLES; AND MAXIMAL HIP ANGLES

Subject	Strength Scores (Pounds)			Initial Hip Angle (Degrees)			Maximal Hip Angle (Degrees)		
	1	Trial 2	3	1	Trial 2	3	1	Trial 2	3
1	240	260	265	150.0	149.5	151.0	154.0	154.5	157.0
2	250	235	255	164.0	163.5	165.0	167.5	167.5	169.5
3	330	405	425	164.5	163.5	163.5	167.0	164.0	164.5
4	465	465	515	165.5	166.0	169.0	178.5	177.5	177.0
5	210	200	215	148.5	148.0	148.5	150.5	152.0	152.5
6	305	360	365	162.0	161.5	164.0	159.5	164.5	167.0
7	260	350	430	150.0	151.5	148.5	152.0	154.5	153.0
8	190	270	295	148.5	148.5	148.0	153.5	154.5	154.0
9	405	495	540	152.0	151.5	155.0	162.0	160.0	159.0
10	305	320	370	161.0	163.5	162.0	163.0	163.5	167.0
11	300	300	310	153.5	158.0	157.5	158.5	159.0	158.0
12	400	425	465	160.0	166.0	170.0	169.5	173.0	172.0
13	285	300	350	162.5	164.0	161.0	162.5	160.0	160.0
14	240	260	230	157.0	158.5	161.5	160.5	161.0	162.5
15	255	305	335	161.5	162.5	163.5	164.5	167.0	168.0
16	245	235	310	156.0	160.0	157.5	160.0	161.0	162.0
17	610	710	770	159.0	165.0	165.5	164.0	172.0	175.0
18	315	315	320	156.5	156.5	159.0	157.5	159.0	160.5
19	165	160	140	166.5	170.5	168.5	167.5	171.0	170.0
20	215	215	220	175.5	173.5	172.5	182.5	181.0	180.0
21	285	345	410	153.0	152.0	151.5	156.0	156.0	154.5
22	270	270	305	159.0	157.0	161.5	162.5	162.5	162.5
23	300	285	305	157.5	156.5	153.5	159.5	156.0	155.0
24	210	225	235	160.0	159.0	159.5	167.0	165.5	167.5

MEAN STRENGTH SCORES OF TRIALS TWO AND THREE
AND CORRESPONDING MEAN RANGES OF HIP ANGLES

Subject	Strength Scores				Angle Ranges			
	Mean of Trials Two and Three				Mean Range of Trials Two and Three			
	Test A	Test B	Test C	Test D	Test A	Test B	Test C	Test D
1	350.0	377.5	270.0	265.5	+ 3.75	+ 2.25	+ 2.50	+ 5.50
2	365.0	312.5	307.5	245.0	+ 5.50	+ 5.00	+11.25	+ 4.25
3	355.0	365.0	500.0	415.0	+ 6.00	+ 3.25	+12.50	+ 0.75
4	480.0	472.5	487.5	490.0	- 5.50	+ 5.25	+ 5.00	+ 9.75
5	235.0	275.0	215.0	207.5	- 1.75	- 0.75	+ 7.75	+ 4.00
6	212.5	212.5	322.5	362.5	+ 1.25	- 2.50	- 2.25	+ 3.00
7	350.0	360.0	410.0	390.0	+ 4.75	+ 2.25	+ 2.50	+ 3.75
8	387.5	375.0	347.5	282.5	- 1.00	- 1.75	+ 7.50	+ 6.00
9	402.5	427.5	457.5	517.5	+ 1.50	+ 0.75	+ 7.25	+ 6.25
10	395.0	370.0	415.0	345.0	- 1.00	- 1.25	+ 7.25	+ 2.50
11	412.5	385.0	282.5	305.0	0.00	+ 1.25	+ 8.25	+ 0.75
12	432.5	430.0	405.0	445.0	+ 1.75	+ 1.50	+ 3.00	+ 4.50
13	375.0	385.0	347.5	325.0	- 1.25	- 2.25	+ 4.75	- 2.50
14	270.0	220.0	272.5	245.0	- 2.75	- 0.75	+10.00	+ 1.75
15	312.5	310.0	307.5	320.0	- 4.50	- 3.50	+ 0.25	+ 4.50
16	375.0	385.0	400.0	272.5	+ 1.00	0.00	+ 8.25	+ 2.75
17	592.5	565.0	642.5	740.0	- 0.50	- 0.25	+ 3.50	+ 8.25
18	257.5	262.5	322.5	317.5	+ 0.50	+ 1.00	+ 2.75	+ 2.00
19	315.0	292.5	312.5	150.0	+ 4.50	- 2.00	+ 8.75	+ 1.00
20	230.0	215.0	227.5	217.5	+ 2.50	+ 1.25	+ 5.00	+ 7.50
21	375.0	320.0	362.5	377.5	+ 3.00	+ 2.75	+ 4.00	+ 3.50
22	297.5	365.0	265.0	287.5	+ 1.00	+ 1.25	+ 0.50	+ 5.50
23	405.0	370.0	397.5	295.0	+ 0.25	+ 3.25	+ 9.75	+ 0.50
24	260.0	262.5	257.5	230.0	+ 0.75	- 4.50	+11.00	+ 7.25

MEAN STRENGTH SCORES OF TRIALS TWO AND THREE
AND CORRESPONDING MEAN MAXIMAL HIP ANGLE

Subject	Strength Scores				Hip Angles			
	Mean of Trials Two and Three				Mean Maximum of Trials Two and Three			
	Test A	Test B	Test C	Test D	Test A	Test B	Test C	Test D
1	350.0	377.5	270.0	262.5	166.75	164.25	153.25	155.75
2	365.0	312.5	307.5	245.0	172.50	176.25	176.25	168.50
3	355.0	365.0	500.0	415.0	164.00	166.00	165.50	164.25
4	480.0	472.5	487.5	490.0	157.50	174.75	173.25	177.25
5	235.0	275.0	215.0	207.5	151.00	152.25	157.25	152.25
6	212.5	212.5	322.5	362.5	156.25	148.50	156.00	165.75
7	350.0	360.0	410.0	390.0	169.25	163.75	161.00	153.75
8	387.5	375.0	347.5	282.5	157.75	148.75	151.25	154.25
9	402.5	427.5	457.5	517.5	151.75	162.75	161.50	159.50
10	395.0	370.0	415.0	345.0	168.25	172.50	173.75	165.25
11	412.5	385.0	282.5	305.0	157.00	156.00	163.75	158.50
12	432.5	430.0	405.0	445.0	165.50	163.00	157.75	172.50
13	375.0	385.0	347.5	325.0	165.50	158.25	172.75	160.00
14	270.0	220.0	272.5	245.0	161.75	163.00	172.50	161.75
15	312.5	310.0	307.5	320.0	159.50	162.25	158.75	167.50
16	375.0	385.0	400.0	272.5	168.75	167.00	167.75	161.50
17	592.5	565.0	642.5	740.0	163.25	164.75	168.00	173.50
18	257.5	262.5	322.5	317.5	158.00	154.50	161.50	159.75
19	315.0	292.5	312.5	150.0	172.00	167.50	172.00	170.50
20	230.0	215.0	227.5	217.5	172.75	150.25	154.25	180.50
21	375.0	320.0	362.5	377.5	155.00	167.25	160.25	155.25
22	297.5	365.0	265.0	287.5	156.50	171.50	150.50	162.50
23	405.0	370.0	397.5	295.0	153.00	160.75	157.50	155.50
24	260.0	262.5	257.5	230.0	163.75	157.50	170.75	166.50

MAXIMUM STRENGTH SCORES AND MAXIMAL HIP ANGLES

Subject	Strength Scores				Hip Angles			
	Test A	Test B	Test C	Test D	Test A	Test B	Test C	Test D
1	350	385	280	265	166.75	164.50	154.50	157.00
2	365	345	310	255	172.50	176.50	177.00	169.50
3	385	375	535	425	164.50	165.00	158.50	164.50
4	490	485	500	515	154.50	175.00	172.00	177.00
5	260	285	220	215	153.00	152.50	158.00	152.50
6	225	230	345	365	156.00	142.50	157.00	167.00
7	355	385	425	430	170.50	161.00	162.00	153.00
8	410	380	355	295	157.00	149.50	152.50	154.00
9	410	430	475	540	152.00	163.00	161.00	159.00
10	410	395	440	370	169.00	171.00	174.00	167.00
11	415	405	325	310	157.00	156.00	164.00	158.00
12	445	435	445	465	167.50	167.50	157.50	172.00
13	380	395	355	350	163.00	157.50	173.50	160.00
14	290	235	290	260	157.50	164.00	174.00	161.00
15	320	320	355	335	160.00	155.00	158.50	168.00
16	380	395	410	310	167.00	164.00	168.00	162.00
17	595	595	685	770	162.50	170.50	168.00	175.00
18	260	265	335	320	157.75	155.00	159.50	160.50
19	330	305	315	165	171.00	168.00	171.00	167.50
20	245	230	230	220	174.00	152.50	155.00	180.00
21	385	340	405	410	155.00	166.50	160.00	154.50
22	305	380	265	305	156.00	172.50	150.50	162.50
23	405	375	400	305	153.00	160.50	159.50	155.00
24	280	265	280	235	167.00	154.00	169.50	167.50

APPENDIX B

FORMULAE

A. Standard Error of Measurement Formula

$$S_m = S_t \sqrt{1-r}$$

Where: S_m = Standard Error of Measurement

S_t = Standard Deviation of Scores

r = Reliability Coefficient

B. Formula For Adjusting Scores

$$X^a = X_i - \left\{ a (Y_i - \bar{Y}) \right\}$$

Where: X^a = Adjusted Score

X_i = Observed Score

a = Regression Coefficient

Y_i = Observed Angle

$\bar{Y}$ = Mean Angle

APPENDIX C
TESTING ORDERS

TESTING ORDERS

TESTS: A; B; C; D

TRIALS: Three

1.	A	B	C	D	13.	C	A	B	D
2.	A	B	D	C	14.	C	A	D	B
3.	A	C	B	D	15.	C	B	A	D
4.	A	C	D	B	16.	C	B	D	A
5.	A	D	B	C	17.	C	D	A	B
6.	A	D	C	B	18.	C	D	B	A
7.	B	A	C	D	19.	D	A	B	C
8.	B	A	D	C	20.	D	A	C	B
9.	B	C	A	D	21.	D	B	A	C
10.	B	C	D	A	22.	D	B	C	A
11.	B	D	A	C	23.	D	C	A	B
12.	B	D	C	A	24.	D	C	B	A

Test A: Traditional Bar, Experimental Back-Lift Dynamometer, load cell, recorders, electrogoniometer.

Test B: Traditional Bar, Experimental Back-Lift Dynamometer, preventing back lunge, load cell, recorders, electrogoniometer.

Test C: Experimental Shoulder Harness and Self-Contained Bar, Experimental Back-Lift Dynamometer, load cell, recorders, electrogoniometer, without hands.

Test D: Experimental Shoulder Harness and Self-Contained Bar, Experimental Back-Lift Dynamometer, preventing back lunge, load cell, recorders, electrogoniometer, without hands.

APPENDIX D
DATA COLLECTION SHEET

DATA SHEET

NAME _____ TESTING ORDER _____

AGE (years and months) _____ WEIGHT _____ HEIGHT _____

FACULTY _____ YEAR _____

TEST _____ SCORES FOR TRIALS 1 _____ ANGLE _____

DATE _____ 2 _____

TIME _____ 3 _____

TEST _____ SCORES FOR TRIALS 1 _____ ANGLE _____

DATE _____ 2 _____

TIME _____ 3 _____

TEST _____ SCORES FOR TRIALS 1 _____ ANGLE _____

DATE _____ 2 _____

TIME _____ 3 _____

TEST _____ SCORES FOR TRIALS 1 _____ ANGLE _____

DATE _____ 2 _____

TIME _____ 3 _____

DATE: TEST A TEST B TEST C TEST D

BEST	AVE.

BEST	AVE.

BEST	AVE.

BEST	AVE.

APPENDIX E
ANTHROPOMETRICAL DATA

ANTHROPOMETRICAL DATA

Subject	Age (years and months)	Weight (pounds)	Height (inches)
1	25, 3	180	72.50
2	25, 9	174	69.00
3	33, 2	165	70.00
4	28, 8	175	73.00
5	29, 6	148	68.00
6	22, 7	143	65.50
7	21, 10	178	71.00
8	22, 4	150	67.00
9	26, 6	165	72.00
10	23, 2	180	72.00
11	24, 2	170	70.00
12	26, 11	160	70.00
13	35, 5	180	70.00
14	26, 10	135	67.00
15	22, 11	130	66.00
16	27, 9	142	66.00
17	24, 11	180	72.00
18	24, 10	140	68.00
19	21, 10	145	69.00
20	28, 2	123	66.00
21	25, 4	174	70.50
22	25, 3	160	68.00
23	23, 3	155	70.25
24	24, 2	150	68.00

APPENDIX F

CALIBRATION OF THE ELECTROGONIOMETER

CALIBRATION OF THE ELECTROGONIOMETER

The electrogoniometer was calibrated at the start of each testing period according to the following steps:

1. Tape elgon. to the manual goniometer.
2. Connect elgon. cable to the calibration meter.
3. Shift the "Manual-Recorder" switch on the meter to "M."
4. Adjust the needle position on the meter to the centre of the scale with the help of two balancing knobs so that the needle movement is minimum when the sensitivity knob is rotated.
5. Shift the "Manual-Recorder" switch to "R."
6. Obtain a calibration recording on the Dynograph while moving the manual goniometer (along with the elgon.) five degrees at a time. Use the recording (goniogram) as a reference for analysis of the records obtained during testing of a subject.

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